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A new early Smithian ammonoid fauna from the Salt Range (Pakistan)

Thomas Brühwiler · Hugo Bucher · Ghazala Roohi · Aamir Yaseen · Khalil Rehman

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Abstract Recent extensive investigations in the Salt Range (Pakistan) yielded abundant, well-preserved ammonoid faunas of earliest to latest Smithian age that provided the basis for a major revision of Smithian ammonoid taxonomy and for the establishment of a high-resolution biostratigraphic sequence. Here, an additional new ammonoid fauna of typical early Smithian affinity from the uppermost part of the Ceratite Sandstone of the Nammal Gorge section is described. The new fauna, termed *Euflemingites cirratus* beds, is bracketed between the underlying early Smithian "*Flemingites flemingianus* beds", here renamed *Clypeoceras superbum* beds, and the overlying middle Smithian *Brayardites compressus* beds. Comparison with a recently published high-resolution biochronological scheme for the Smithian of the NIM (northern Indian Margin) based on the Salt Range, Spiti (Himachal Pradesh, northern India) and Tulong (South Tibet) basins shows that the *Euflemigites cirratus* fauna correlates with the *Dieneroceras* beds from Spiti based on the common occurrence of the ammonoid species *Kraffticeras pseudoplanulatum*. The trans-panthalassic biogeographical distribution of *Euflemingites cirratus* allows correlating the new ammonoid fauna with part of the *Meekoceras gracilitatis* ammonoid zone of western USA. Three new species (*Kashmirites weisserti*, *Arctoceras schalteggeri* and *Vercherites wyleri*) are described.

Keywords Ammonoidea · Early Triassic · Smithian · Salt Range · Pakistan · Biostratigraphy

Introduction

Since the late nineteenth century, the Salt Range in Pakistan has been a classic locality for the research on Early Triassic ammonoids thanks to the pioneering contribution of Waagen (1895). Recent extensive investigations in the Salt Range have yielded abundant, well-preserved ammonoid faunas of earliest to latest Smithian age (Brühwiler et al. 2011b). This newly collected material provided the basis for a profound revision of the taxonomy of Smithian ammonoids. It also enabled the establishment of a much higher-resolution biostratigraphic sequence for the Smithian of the Salt Range in comparison with previous ammonoid zonations for this area (Mojsisovics et al. 1895; Waagen 1895; Frech 1905; Guex 1978). The biochronological treatment of these data together with those from two other well-documented basins (Tulong, South Tibet, Brühwiler et al 2010b and Spiti, northern India, Brühwiler et al. 2011a) by means of the Unitary Associations method (Guex 1991) has resulted in a biochronological scheme of unprecedented high resolution for the Smithian of the NIM (Brühwiler et al. 2010a). This zonation comprises 16 Unitary Associations grouped into 13 zones for the entire Smithian. Our most recent investigations in the Nammal Gorge in the Salt Range have led to the discovery of an additional new ammonoid fauna of early Smithian age.

T. Brühwiler (✉) · H. Bucher
Paläontologisches Institut und Museum der Universität Zürich, Karl Schmid-Strasse 4, 8006 Zurich, Switzerland
e-mail: bruehwiler@gmx.net

H. Bucher
e-mail: hugo.fr.bucher@pim.uzh.ch

G. Roohi · A. Yaseen · K. Rehman
Earth Science Division, Pakistan Museum of Natural History, Garden Avenue, Shakarparian, Islamabad 44000, Pakistan
e-mail: roohighazala@yahoo.com

A. Yaseen
e-mail: geologistgeologist@yahoo.com

K. Rehman
e-mail: reman_geol@yahoo.com

Herein, we focus on the taxonomic description and the biostratigraphic significance of this ammonoid fauna.

Paleogeographical and geological settings

During the Early Triassic, the Pangean supercontinent was surrounded by two wide oceans, namely the Panthalassa and the Tethys, and several microcontinents (e.g., Cimmerian and Cathaysian) crossed these two oceans (e.g., Tozer 1982; Ricou 1994; Ehiro et al. 2005). During this period, the Salt Range area was located on the northern Gondwanan margin, about 30° south of the equator on the southern side of the Tethys Ocean (e.g., Smith et al. 1994; Stampfli and Borel 2002) (Fig. 1a).

Waagen (1895) subdivided the Lower Triassic sediments of the Salt Range as follows (from bottom to top): Lower Ceratite Limestone (LCL), Ceratite Marls (CM), Ceratite Sandstone (CS), Upper Ceratite Limestone (UCL), Bivalve Beds (BB), Dolomitic Beds, and Topmost Limestone. These

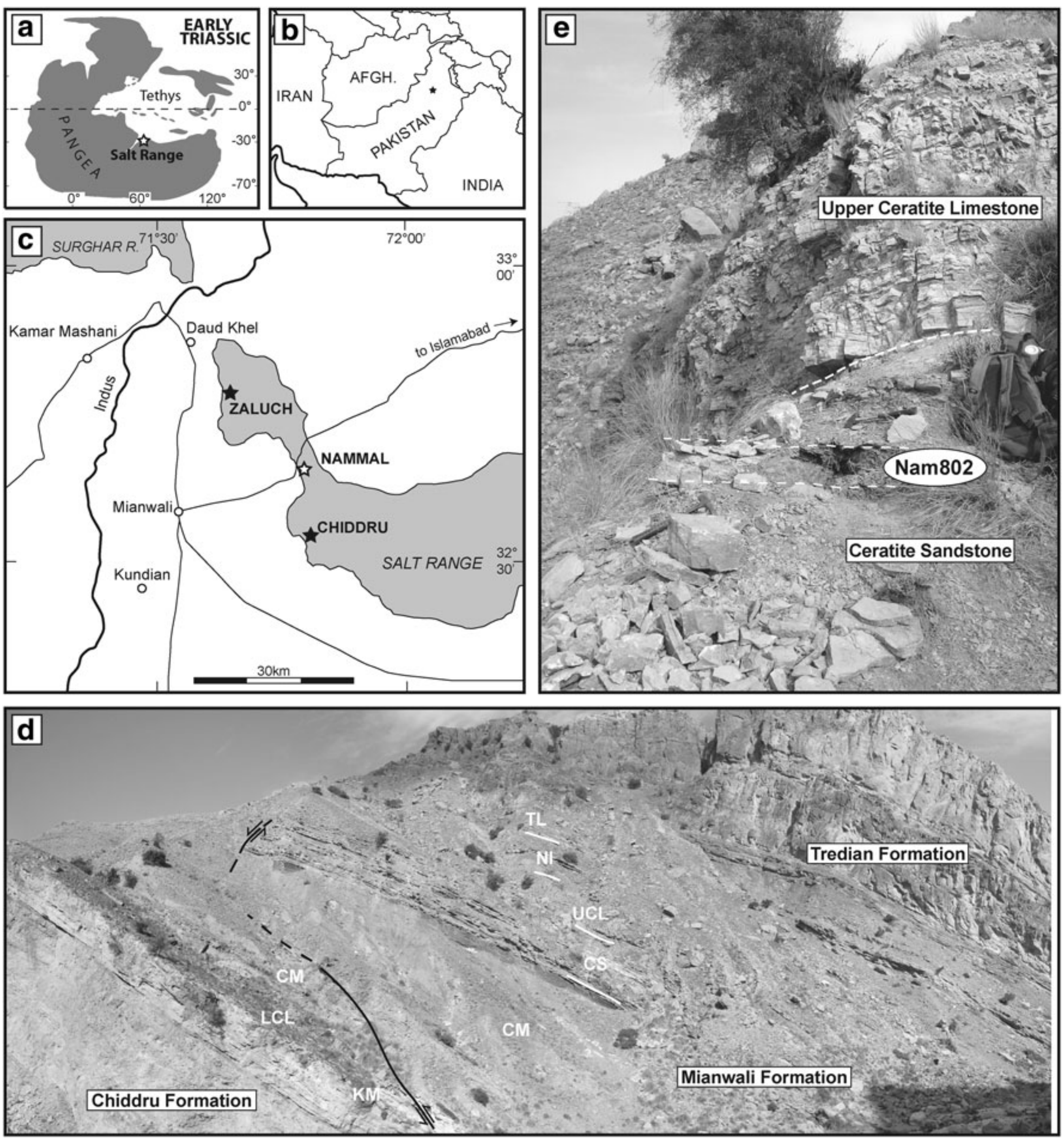


Fig. 1 **a** Paleogeographical map of the Early Triassic with the paleoposition of the Salt Range (modified after Brayard et al. 2006). **b** Map of Pakistan with indication of the studied area. **c** Location map of the Nammal section in the Salt Range. **d** Northwestern slope of the Nammal Gorge. KM Kathwai Member; LCL Lower Ceratite Limestone; CM Ceratite Marls; CS Ceratite Sandstones; UCL Upper Ceratite Limestone; NI Niveaux Intermédiaires; TL Topmost Limestone. Note the presence of normal and low angle reverse faults (*black lines*). **e** Outcrop photograph of the uppermost CS and the lower part of the UCL with indication of sample Nam802

lithological subdivisions can easily be identified in all sections studied by Brühwiler et al. (2011b), and we use them in this paper. A few minor modifications have been adapted from Kummel and Teichert [1970; Kathwai Member (KM)] and Guex [1978; "Niveaux Intermédiaires" (NI)]. For a thorough description of the Lower Triassic sedimentary evolution of the Salt Range, see Hermann et al. (2011).

A new ammonoid fauna: the *Euflemingites cirratus* fauna

The ammonoid fauna described herein was collected from a ca. 15-cm thick limestone bed in the uppermost part of the CS of the Nammal Gorge section (Figs. 1, 2; sample Nam802). This distinct bed is found in all sections within the Nammal Gorge area. It is usually devoid of ammonoids, with the exception of a newly investigated section located in the mouth of the canyon where it yielded a distinct assemblage of very well-preserved ammonoids. It is located about 2 m above a conspicuous sandy carbonate horizon, which yields abundant and large-sized specimens of *Clypeoceras superbum*, *Flemingites flemingianus* and *Hedenstroemia evoluta* (Waagen 1895, Brühwiler et al. 2011b) and 1 m below the base of the UCL. The ammonoid fauna from sample Nam802 is characterized by the co-occurrence of *Arctoceras schalteggeri* sp. nov., *Euflemingites cirratus*, *Flemingites flemingianus*, *Juvenites* sp.

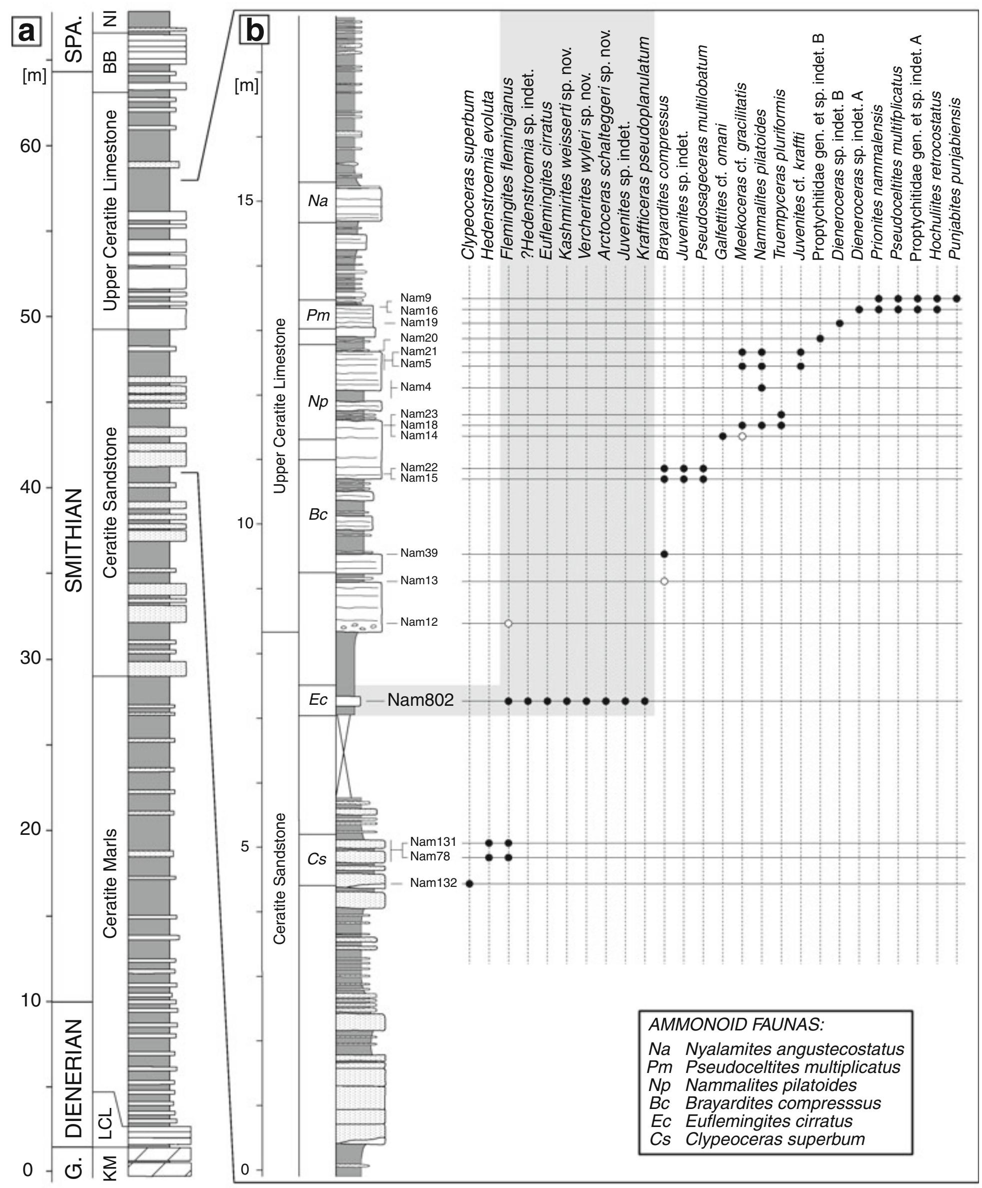


Fig. 2 **a** Simplified stratigraphic section of the Griesbachian-Early Spathian sediments at Nammal Gorge, Salt Range, Pakistan. Abbreviations as in Fig. 1. **b** Detailed profile of the upper CS and the lower UCL with ammonoid content of sample Nam802 (this work) and other samples (from Brühwiler et al. 2011b)

indet., *Kraffticeras pseudoplanulatum*, *Kashmirites weisserti* sp. nov., *Vercherites wyleri* sp. nov. and ?*Hedenstroemia* sp. indet. It is the first record of *Euflemingites* in the Salt Range. The specific assignment to *E. cirratus* (White) leads to the recognition of one of the few globally distributed early Smithian ammonoid species (Idaho, Chulitna Terrane in Alaska, NE British Columbia, Spitsbergen, South China) (Tozer 1994, and discussion in the "Systematic paleontology" section).

Discussion

Biostratigraphy

The *Euflemingites cirratus* fauna described herein is bracketed between the underlying early Smithian "*Flemingites flemingianus* beds" and the overlying middle Smithian *Brayardites compressus* beds (Brühwiler et al. 2011b; Figs. 2, 3). Five species have been found exclusively within the present fauna, thus clearly distinguishing it from all other known ammonoid associations in the Salt Range. However, the species *F. flemingianus* occurs both in the "*F. flemingianus* beds" of Brühwiler et al. (2011b) and in the *E. cirratus* beds. Therefore, the "*F. flemingianus* beds" are here renamed *Clypeoceras superbum* beds.

Figure 4 shows the updated stratigraphic distribution of the ammonoid genera in the Smithian of the Salt Range (Brühwiler et al. 2011b; this work). Four of the eight genera reported from the *Euflemingites cirratus* beds (*Flemingites*, *Hedenstroemia*, *Vercherites*, *Kashmirites*) are of typical early Smithian age. Three genera (*Arctoceras*, *Euflemingites*, *Kraffticeras*) are known only from the *Euflemingites cirratus* beds in the Salt Range, but for instance in South China, *Arctoceras* occurs in the early Smithian (Brayard and Bucher 2008). One genus (*Juvenites*) from the *Euflemingites cirratus* beds is known also from the middle Smithian *Brayardites compressus* beds, but elsewhere, this genus has also been reported from the early Smithian (e.g., Brayard and Bucher 2008). Thus, in summary, the fauna from sample Nam802 clearly exhibits more generic affinities with early Smithian faunas than with middle Smithian ones. Therefore, the *Euflemingites cirratus* beds are here attributed to the early Smithian (Fig. 5).

Recently, we presented a biochronological scheme of unprecedented high resolution for the Smithian of the NIM based on the Salt Range, Spiti (Himachal Pradesh, northern India) and Tulong (South Tibet) basins (Brühwiler et al. 2010a). In the Spiti area, a local Unitary Association was detected between the *Flemingites flemingianus* beds and the *Brayardites compressus* beds (i.e., the *Dieneroceras* beds). Because of its poor lateral reproducibility, it was then merged with the *Flemingites flemingianus* beds based on their similar faunal content instead of being retained as a distinct zone. The inclusion of the *Euflemigites cirratus* fauna from the Salt Range described herein within the data set used in our previous work (see Brühwiler et al. 2010a for a methodological description) shows that the *Euflemigites cirratus* fauna correlates with the *Dieneroceras* beds from Spiti based on the common occurrence of the ammonoid species *Kraffticeras pseudoplanulatum* (Unitary

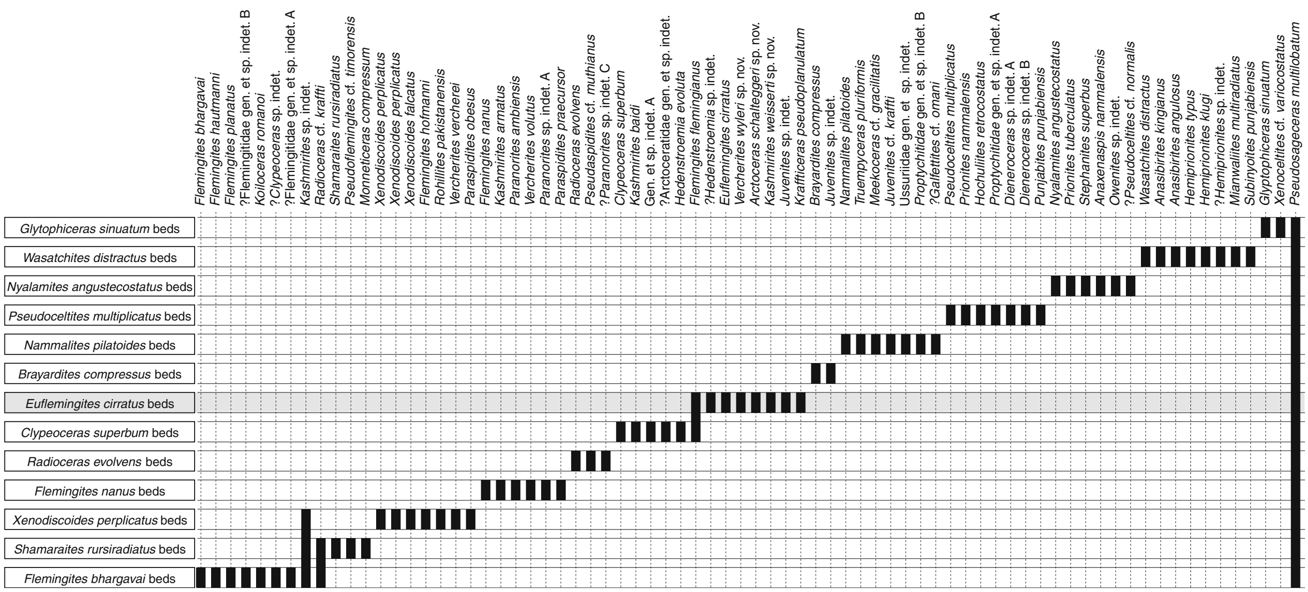


Fig. 3 Synthetic range chart showing the biostratigraphic distribution of Smithian ammonoid species in the Salt Range; based on Brühwiler et al. (2011b) and this work. Note that the *Clypeoceras superbum* beds were previously termed "*Flemingites flemingianus* beds" (Brühwiler et al. 2011b), but are renamed here because the species *F. flemingianus* occurs also in the *Euflemingites cirratus* beds

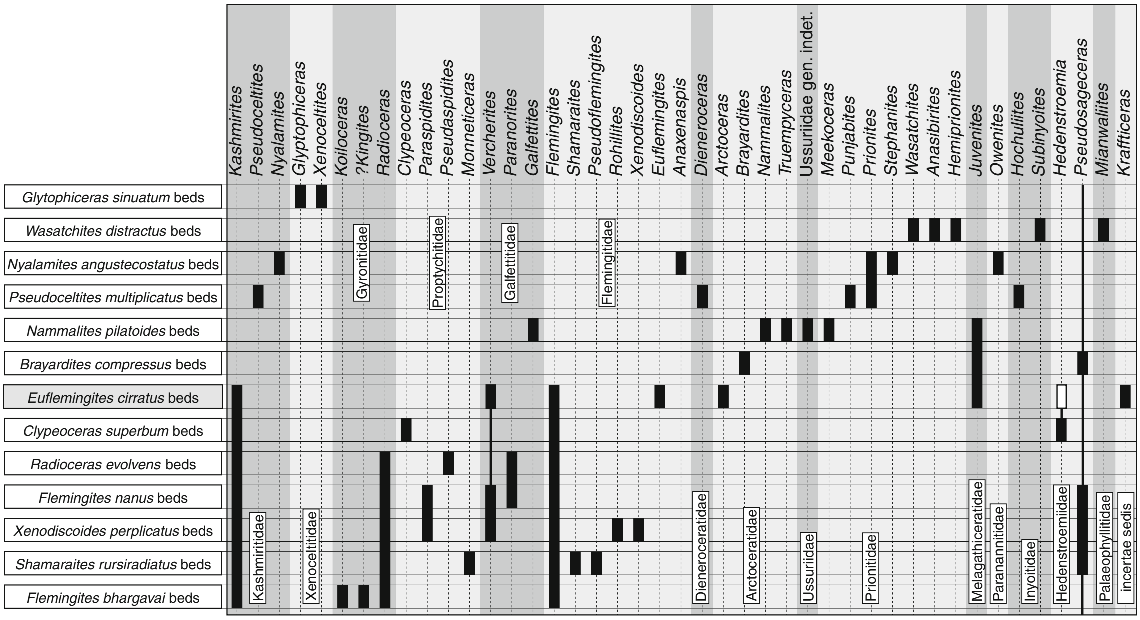


Fig. 4 Synthetic range chart showing the biostratigraphic distribution of Smithian ammonoid genera (grouped by families) in the Salt Range; based on Brühwiler et al. (2011b) and this work

Local Unitary Associations: Salt Range	Spiti	Tulong	NIM: UAs	UA-Zones		
Columbitidae		*Nordophiceras*				SPATHIAN
	Tirolites					
Glyptophiceras sinuatum beds	*Glyptophiceras sinuatum* beds	*Glyptophiceras sinuatum* beds	NIM-16	S-14	LATE	SMITHIAN
	Subvishnuites beds		NIM-15			
Wasatchites distractus beds	*Wasatchites distractus* beds	*Wasatchites distractus* beds	NIM-14	S-13		
Nyalamites angustecostatus beds	*Nyalamites angustecostatus* beds	*Nyalamites angustecostatus* beds	NIM-13	S-12	MIDDLE	
Pseudoceltites multiplicatus beds	*Pseudoceltites multiplicatus* beds	*Pseudoceltites multiplicatus* beds	NIM-12	S-11		
Nammalites pilatoides beds	*Shigetaceras* horizon	*Nammalites pilatoides* beds	NIM-11	S-10		
	Escarguelites horizon		NIM-10	S-9		
Brayardites compressus beds	*Brayardites compressus* beds	*Brayardites compressus* beds	NIM-9	S-8		
Euflemingites cirratus beds	*Dieneroceras* beds		NIM-8	S-7	EARLY	
Clypeoceras superbum beds	*Flemingites flemingianus* beds		NIM-7	S-6		
	Rohillites rohilla zone		NIM-6	S-5		
Radioceras evolvens beds			NIM-5	S-4		
Flemingites nanus beds	*Vercherites pulcher* beds		NIM-4			
Xenodiscoides perplicatus beds			NIM-3	S-3		
Shamaraites rursiradiatus beds	Kashmiritidae gen. nov. beds		NIM-2	S-2		
Flemingites bhargavai beds	*Flemingites bhargavai* beds		NIM-1	S-1		
Prionolobus rotundatus beds	*Prionolobus rotundatus* beds					DIEN.

Fig. 5 Biostratigraphic subdivisions of the Smithian of the Salt Range and correlation with zonations of other areas on the northern Indian Margin; based on Brühwiler et al. (2010a) and this work. Thick black bars indicate uncertainty intervals for correlations. See text for "Discussion"

Association NIM-8 in Fig. 5). Therefore, this Unitary Association is now regarded as a distinct ammonoid zone (UA-Zone S-7 in Fig. 5). This results in a total of 14 UA-Zones for the entire Smithian of the NIM instead of the 13 zones described earlier (Brühwiler et al. 2010a).

As mentioned earlier, detailed correlations of the high-resolution biostratigraphic scheme of the NIM with sections from outside the Tethys are hampered by the still somewhat inadequate knowledge of Smithian ammonoid faunas from these areas on the one hand, and by the latitudinally restricted distribution of most early-middle Smithian ammonoids on the other hand (Brayard et al. 2009a, Brühwiler 2010b). So far, the *Euflemingites cirratus* beds from the Salt Range do not have an exact correlation outside of the Tethys. Obviously, they correlate with a part of the *Meekoceras gracilitatis* Zone of the Western USA, from which the species *E. cirratus* has first been described (Smith 1932; Silberling and Tozer 1968), but this zone contains also significantly younger middle Smithian ammonoids such as *Inyoites* or *Guodunites* (Brayard et al. 2009a). Although known for a long time, the *Meekoceras gracilitatis* Zone is still not well defined and needs a deep reappraisal that could partly explain the observed discrepancies with the Tethyan zonation. In addition, the *E. cirratus* beds from the Salt Range certainly correlate with part of the *Euflemingites romunduri* Zone of the boreal realm (Tozer 1994) based on the common occurrence of the genus *Euflemingites*, but as mentioned earlier this zone contains both early and middle Smithian ammonoids (Brühwiler et al. 2010b).

Diversity dynamics

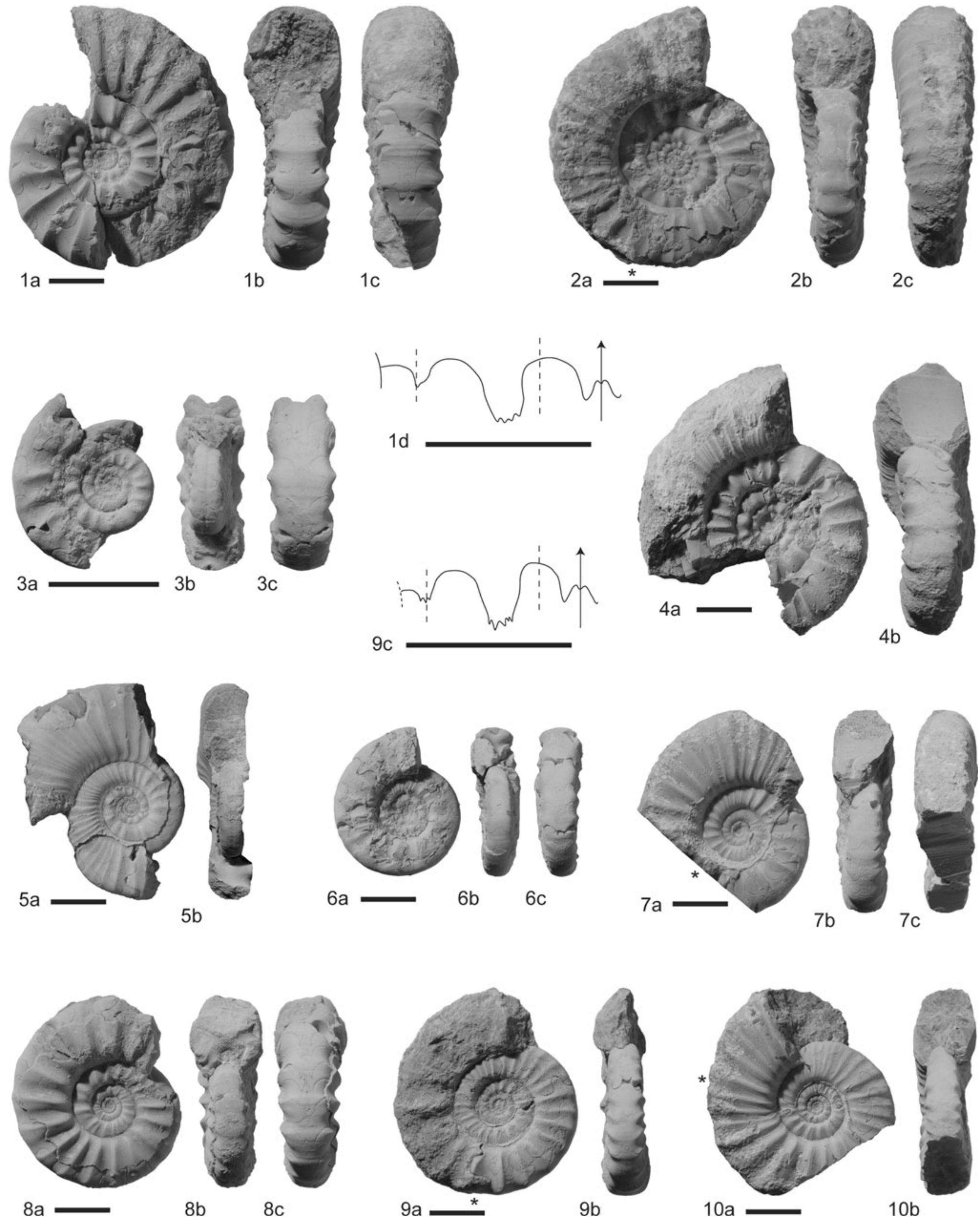
Based on our new highly resolved time frame, we recently provided an analysis of ammonoid diversity dynamics of the Smithian of the NIM (Brühwiler et al. 2010a). This highlighted (1) a marked diversification during the early Smithian, (2) a severe extinction during the late Smithian and (3) an overall very high turnover throughout the Smithian. Results of that work focusing only on the Smithian substage thus confirmed the very high evolutionary tempo of Early Triassic ammonoids, as previously shown in a larger scale analysis (Brayard et al. 2009b). The new ammonoid data presented herein were incorporated into that data set. Recalculation of diversity, origination, extinction and turnover at the species and genus levels (see Brühwiler et al. 2010a for methodological description) revealed no significant difference with the data presented earlier. Thus, the new fauna closely matches the known patterns and does not alter the interpretations of the diversity dynamics of Smithian ammonoids by Brühwiler et al. (2010a). Comparison of our high-resolution biostratigraphic data with recently published U/Pb ages from South China (Ovtcharova et al. 2006; Galfetti et al. 2007) led to a very short estimated average zone duration of 67 ky per Smithian ammonoid zone of the NIM (inclusive of the intervals of separation intercalated between the zones; Brühwiler et al. 2010a). A recalculation including the additional *Euflemingites cirratus* fauna described herein results in an even shorter estimated average zone duration of 61 ky.

Plate 1 Figs. 1–10. *Kashmirites weisserti* sp. nov.; from sample ► Nam802, uppermost Ceratite Sandstone, Nammal, Salt Range, Pakistan; *Euflemingites cirratus* beds, early Smithian. **1a–d** PIMUZ 28552, holotype. **2a-c** PIMUZ 28557. **3a–c** PIMUZ 28556. **4a–b** PIMUZ 28573. **5a–b** PIMUZ 28569 (This specimen is attached to a large specimen of *Euflemingites cirratus*, see Plate 2, **Fig. 1a**. **6a–c** PIMUZ 28574. **7a–c** PIMUZ 28571. **8a–c** PIMUZ 28554. **9a–c** PIMUZ 28555. **10a–b** PIMUZ 28553. All *scale bars* 1 cm. *Asterisks* indicate phragmocone end where known

Conclusions

Recent investigations in the Nammal Gorge section in the Salt Range (Pakistan) have led to the discovery of an additional ammonoid fauna of typical early Smithian affinity from the uppermost part of the Ceratite Sandstone. The present description of this fauna complements the recently published comprehensive monograph on the Smithian ammonoids of the Salt Range (Brühwiler et al. 2011b). The fauna is characterized by the co-occurrence of *Arctoceras schalteggeri* sp. nov., *Euflemingites cirratus*, *Flemingites flemingianus*, *Juvenites* sp. indet., *Kraffticeras pseudoplanulatum*, *Kashmirites weisserti* sp. nov., *Vercherites wyleri* sp. nov., and ?*Hedenstroemia* sp. indet. The fauna, termed *Euflemingites cirratus* beds, is bracketed between the underlying early Smithian "*Flemingites flemingianus* beds", which are here renamed *Clypeoceras superbum* beds, and the overlying middle Smithian *Brayardites compressus* beds.

The comparison with our recently published high-resolution biochronological scheme for the Smithian of the NIM based on the Salt Range, Spiti (Himachal Pradesh, northern India) and Tulong (South Tibet) basins (Brühwiler et al. 2010a) shows that the *Euflemigites cirratus* fauna correlates with the *Dieneroceras* beds from Spiti based on the common occurrence of the ammonoid species *Kraffticeras pseudoplanulatum*. This leads to the establishment of an additional Unitary Association Zone for the NIM. Previously, this zone was found in the Spiti area only and merged with the underlying *Flemingites* beds due to its then poor lateral reproducibility.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Systematic paleontology

by Thomas Brühwiler and Hugo Bucher

Systematic descriptions mainly follow the classification established by Tozer (1981, 1994) and refined by Brayard and Bucher (2008), Brühwiler et al. (2010b) and Brühwiler and Bucher (2011a, b).

Abbreviations: non = material not forming part of the current species; v. = *video* or *vidimus* (from Latin, means that the material was seen in person by the authors); ? = questionable; PIMUZ, Paläontologisches Institut und Museum der Universität Zürich, Switzerland.

Class Cephalopoda Cuvier 1797

Subclass Ammonoidea Zittel 1884

Order Ceratitida Hyatt 1884

Superfamily Xenodiscaceae Frech 1902

Family Kashmiritidae Spath 1934

Genus *Kashmirites* Diener 1913

Type species. *Celtites armatus* Waagen 1895.

***Kashmirites weisserti* sp. nov.**

Plate 1, Figs. 1–10

Derivation of name. Named for Helmut Weissert (Zürich).

Holotype. Specimen PIMUZ 28552 (Pl. 1, fig. 1a–d).

Type locality. Nammal, Salt Range, Pakistan.

Type horizon. Sample Nam802, top of CS, *Euflemingites cirratus* beds.

Diagnosis. *Kashmirites* with high intraspecific variation regarding strength of ornamentation and whorl section; ornamentation consists of simple ribs that become weak on the ventral shoulders but cross the venter.

Occurrence. Abundant in sample Nam802.

Description. Very evolute shell with slightly flattened flanks exhibiting large intraspecific variation. Whorls vary from slightly compressed to depressed. Venter, broad and subtabulate with rounded shoulders. Umbilicus, wide with inclined to almost vertical wall and rounded shoulders. Ornamentation consists of fine to very strong, straight ribs that become weak on the ventral shoulders but cross the venter. Ribs become fine and dense on the outer whorls. Suture line is with weakly indented lobes and broad saddles; third lateral saddle crosses the umbilical suture.

Measurements. See Fig. 6; Appendix.

Discussion. Variants of this species with weak ornamentation exhibit a slightly more involute coiling as well as a more compressed whorl section than variants with strong ornamentation. This type of covariation is well known as Buckman's first law of covariation (Westermann 1966; Hammer and Bucher 2005). *Kashmirites weisserti* resembles *K. baidi* Brühwiler and Bucher (2011b) that has recently been reported from Oman as well as from the *Clypeoceras superbum* beds of the Salt Range (Brühwiler et al. 2011a, b). However, that species differs by its ornamentation consisting of simple or paired strong, radial ribs. The type species, *K. armatus* (Waagen 1895), clearly differs from *K. weisserti* by its suture line with relatively strongly indented lobes and slightly phylloid saddles as well by its less sharp ribs and its smooth venter.

Family Flemingitidae Hyatt 1900

Genus *Flemingites* Waagen 1895

Type species. *Ceratites flemingianus* De Koninck 1863.

Flemingites flemingianus (De Koninck 1863)

Plate 3, fig. 5.

1863 *Ceratites flemingianus* de Koninck, p. 10, pl. 7, fig. 1.

1895 *Flemingites flemingianus* Waagen, p. 199, pl. 12, fig. 1, pl. 13, fig. 1, pl. 14, fig. 1.

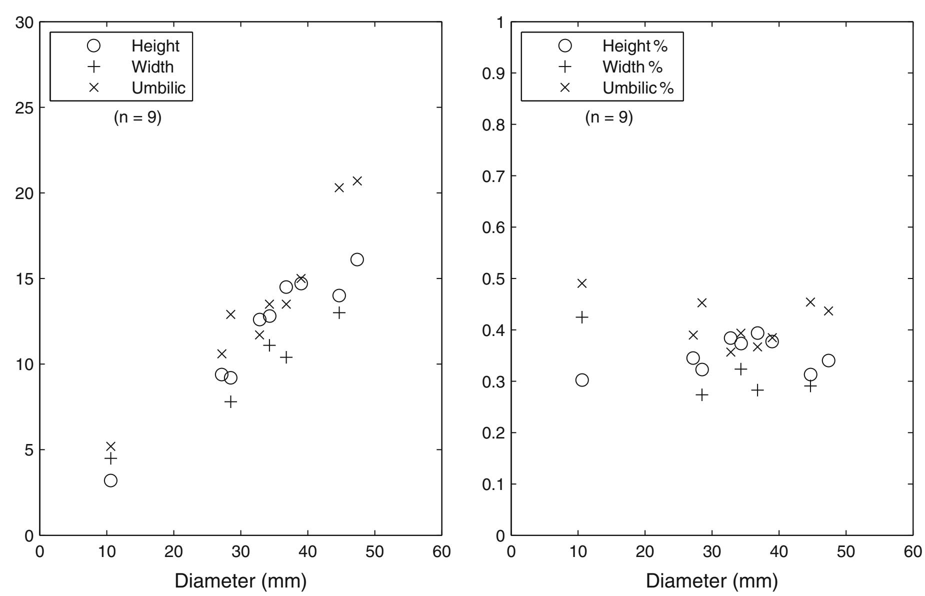


Fig. 6 Scatter diagram of H, W and U, and of H/D, W/D and U/D for *Kashmirites weisserti* sp. nov

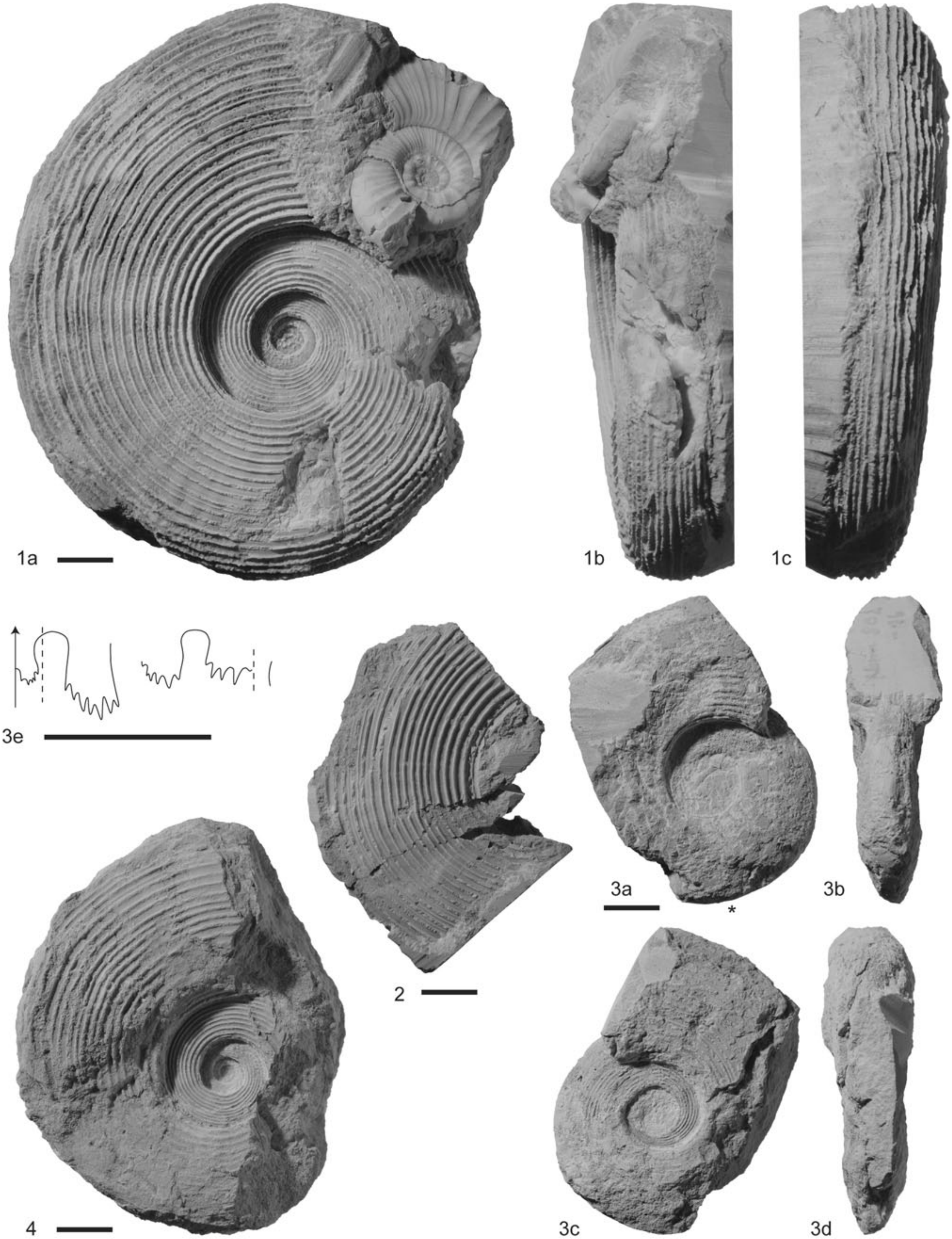
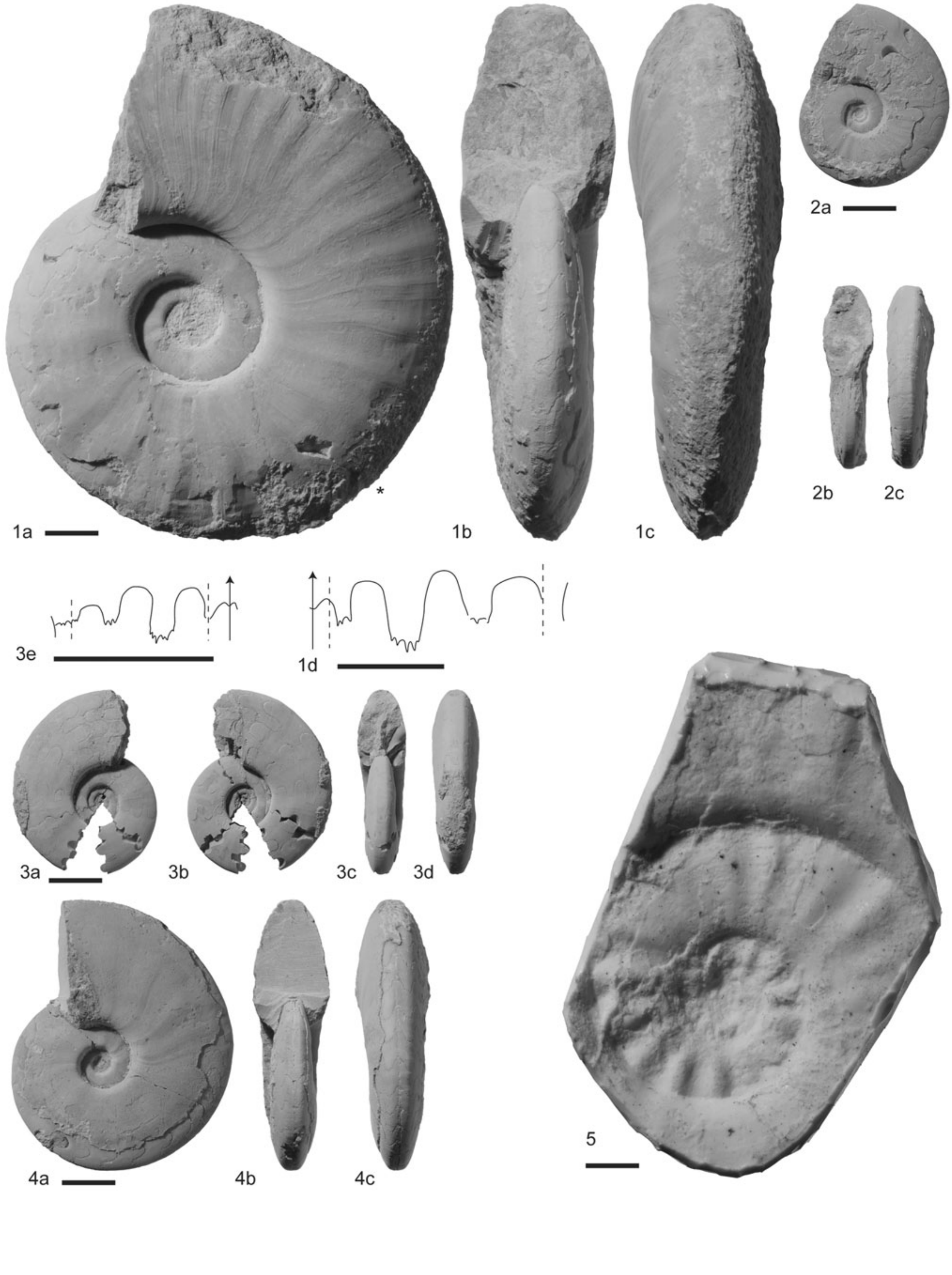


Plate 2 Figs. 1–4. *Euflemingites cirratus* (White 1880); from sample Nam802, uppermost Ceratite Sandstone, Nammal, Salt Range, Pakistan; *Euflemingites cirratus* beds, early Smithian. **1a–c** PIMUZ 28569. **2** PIMUZ 28568. **3a–e** PIMUZ 28567. **4** PIMUZ 28566. All *scale bars* 1 cm. *Asterisk* indicates phragmocone end where known



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◀ **Plate 3** **Figs. 1–4.** *Vercherites wyleri* sp. nov.; from sample Nam802, uppermost Ceratite Sandstone, Nammal, Salt Range, Pakistan; *Euflemingites cirratus* beds, early Smithian. **1a–d** PIMUZ 28558, holotype. *Asterisk* indicates approximative position of phragmocone end. **2a–c** PIMUZ 28561. **3a–e** PIMUZ 28560. **4a–c** PIMUZ 28559. **Fig. 5.** *Flemingites flemingianus* Waagen 1895; from sample Nam802, uppermost Ceratite Sandstone, Nammal, Salt Range, Pakistan; *Euflemingites cirratus* beds, early Smithian. PIMUZ 28570. All *scale bars* 1 cm

1895 *Flemingites compressus* Waagen, p. 202, pl. 15, fig. 1, pl. 16, fig. 1a–c.

1895 *Flemingites trilobatus* Waagen, p. 193, pl. 26, fig. 2a–b.

1933 *Flemingites compressus* Waagen; Collignon, p. 170, pl. 3, fig. 1, 1a.

1933 *Flemingites flemingi madagascariensis* Collignon, p. 173, pl. 5, fig. 1.

1933 *Flemingites griesbachi* Krafft and Diener; Collignon, p. 176, pl. 4, fig. 3, 3a; pl. 5, fig. 4; pl. 6, fig. 1–2.

v non 2008 *Flemingites flemingianus* Waagen; Brayard and Bucher, p. 43, pl. 17, figs. 1–5; text-fig. 38.

v acc. *Flemingites flemingianus* Waagen; Brühwiler et al.

Occurrence. Three specimens from sample Nam802. This species has previously been reported from a horizon ca. 2 m below this sample at Nammal as well as from several other localities in the Salt Range (Waagen 1895, Brühwiler et al. 2011b; Fig. 2).

Description. Large, evolute shell with elliptical whorl section. Venter, rounded with indistinct shoulders. Umbilicus, wide with rounded wall. Flanks, ornamented with strigation and radial or rursiradiate ribs. Ribs are strongest on inner whorls, but become finer in the outer whorls. Suture line, not preserved.

Discussion. See Brühwiler et al. (2011b) for a recent discussion of this species based on new and well-preserved material from the Salt Range.

Genus *Euflemingites* Spath 1934

Type species. *Flemingites guyerdetiformis* Welter 1922.

***Euflemingites cirratus* (White 1880)**

Plate 2, figs. 1–4

1880 *Arcestes cirratus* White, p. 116.

1932 *Flemingites cirratus* White - Smith, p. 53, pl. 20, fig. 1; pl. 26, figs. 1–12.

? 1947 *Flemingites prynadai* Kiparisova, p. 135, pl. 29, fig. 1; pl. 30, fig. 1; text-fig. 18.

? 1954 *Flemingites prynadai* Kiparisova - Kiparisova and Krishtofovich, p. 18, pl. 8, fig. 1.

1959 *Euflemingites tsotengensis* Chao, p. 209, pl. 5, figs. 1–2.

? 1961 *Flemingites prynadai* Kiparisova - Kiparisova, p. 76, pl. 15, fig. 1a–b, text-fig. 36.

1967 *Euflemingites* cf. *cirratus* White - Tozer, p. 19, 50, 74.

1970 *Euflemingites* cf. *cirratus* White - Korchinskaya, p. 82, pl. 2, fig. 1.

1979 *Euflemingites cirratus* White - Nichols and Silberling, p. B3, pl. 3, figs. 1–3.

1982 *Euflemingites* cf. *cirratus* White - Korchinskaya, pl. 5, fig. 1; pl. 6, fig. 3.

1994 *Euflemingites cirratus* White - Tozer, p. 72, pl. 22, fig. 13; pl. 23, figs. 4–5, 21b.

? 2004 *Euflemingites* cf. *tsotengensis* Chao - Tong et al., p. 200, pl. 2, figs. 13–15.

? 2007 *Euflemingites* sp. - Krystyn et al., pl. 4, figs. 1–2.

? 2009 *Eulemingites prynadai* Kiparisova - Shigeta and Zakharov, p. 100, figs. 87–90.

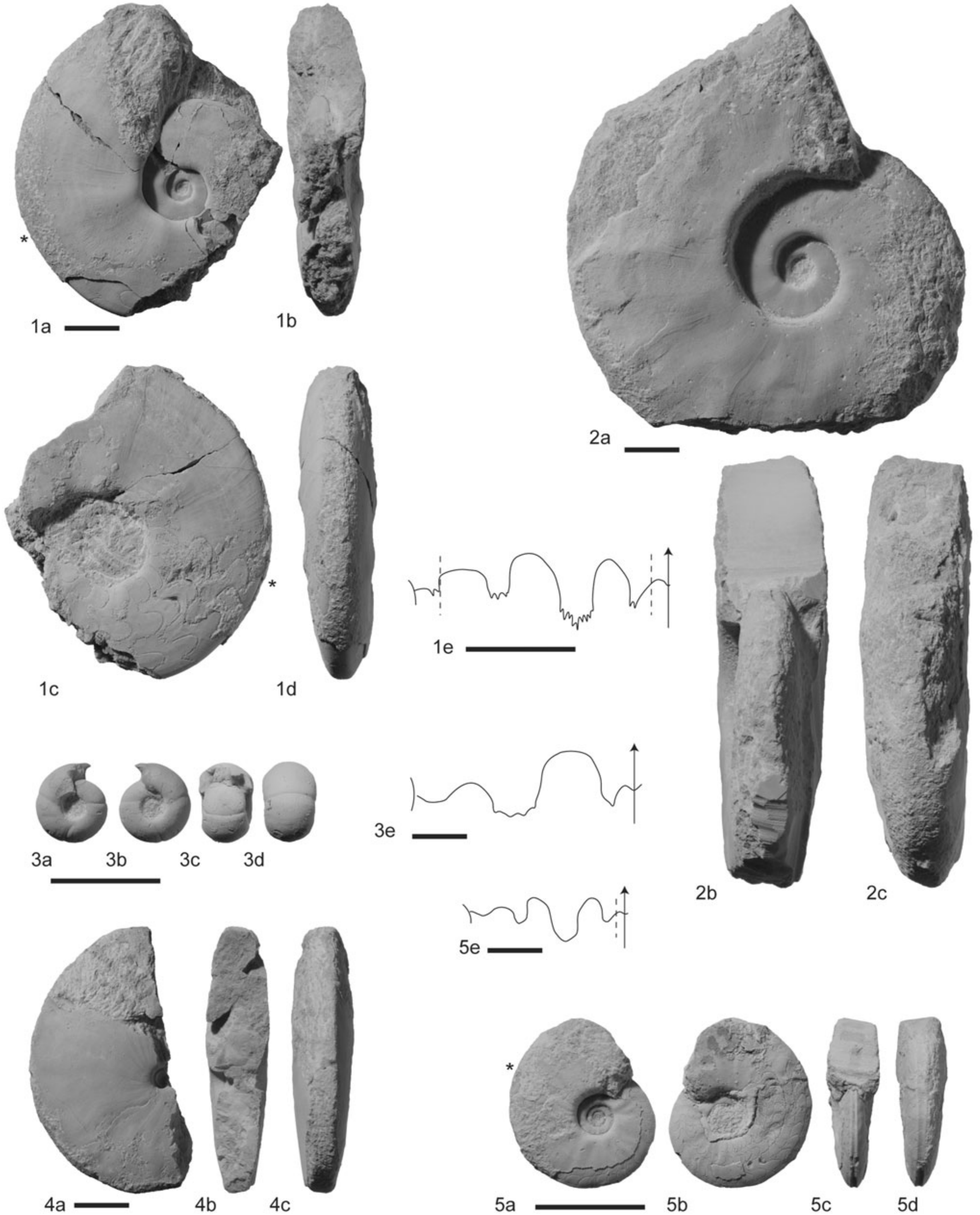
Occurrence. Four specimens from sample Nam802.

Description. Moderately evolute, compressed shell. Flanks, flat and parallel. Venter, rounded and slightly flattened with rounded shoulders. Umbilicus, relatively deep with vertical wall. Ornamentation consists of very coarse strigation on the venter, flanks and umbilical wall. Suture line, ceratitic with long, slightly phylloid saddles and broad, strongly indented lobes.

Measurements. See Appendix.

Discussion. Our new material from the Salt Range is clearly conspecific with the well preserved specimens of *Euflemingites cirratus* from western USA described by Smith (1932). *E. tsotengensis* Chao 1959 from South China does not exhibit any differences from this species and is here considered as a synonym. The specimens described as *E.* cf. *tsotengensis* Chao 1959 by Tong (2004) are too poorly preserved for identification at the species level. *E. prynadai* (Kiparisova 1947) from Primorye is very similar to *E. cirratus* and essentially differs by its larger size. The type species *E. guyerdeti* (Diener 1897), of which only a single small specimen from Spiti is known, differs slightly from *E. cirratus* by its inclined umbilical wall. The specimens from the *Flemingites* beds of Spiti described as *Euflemingites* sp. by Krystyn et al. (2007) may be conspecific with either *E. guyerdeti* or *E. cirratus*, but they are too poorly preserved for identification at the species level. *E. guyerdetiformis* (Welter 1922) from Timor differs from *E. cirratus* by its denser spiral ornamentation. *E. cirratus* has also been reported from the Chulitna Terrane in Alaska, from NE British Columbia and from Spitsbergen (Tozer 1967, 1994; Korchinskaya 1970, 1982; Nichols and Silberling 1979). The boreal species *E. romunduri* Tozer 1961 as well as *E. aryomensis* Smyshlyaeva 2010 from Primorye differ from *E. cirratus* by their thicker whorl section.

Family Arctoceratidae Arthaber 1911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◀ **Plate 4 Figs. 1–2.** *Arctoceras schalteggeri* sp. nov.; from sample Nam802, uppermost Ceratite Sandstone, Nammal, Salt Range, Pakistan; *Euflemingites cirratus* beds, early Smithian. **1a–e** PIMUZ 28563, holotype. **2a–c** PIMUZ 28562. **Fig. 3a–e.** *Juvenites* sp. indet.; from sample Nam802, uppermost Ceratite Sandstone, Nammal, Salt Range, Pakistan; *Euflemingites cirratus* beds, early Smithian. PIMUZ 28564, *scale bar* for **Fig. 3e** = 1 mm. **Fig. 4a–c.** ?*Hedenstroemia* sp. indet.; from sample Nam802, uppermost Ceratite Sandstone, Nammal, Salt Range, Pakistan; *Euflemingites cirratus* beds, early Smithian. PIMUZ 28565. **Fig. 5a–e.** *Kraffticeras* cf. *pseudoplanulatum* (Krafft & Diener 1909); from sample Nam802, uppermost Ceratite Sandstone, Nammal, Salt Range, Pakistan; *Euflemingites cirratus* beds, early Smithian. PIMUZ 28572, *scale bar* for Fig. **5e** = 2 mm, All *scale bars* 1 cm unless otherwise indicated. *Asterisks* indicate phragmocone end where known

Genus *Arctoceras* Hyatt 1900

Type species. *Ceratites polaris* Mojsisovics 1886.

***Arctoceras schalteggeri* sp. nov.**

Plate 4, figs. 1–2

Derivation of name. Named for Urs Schaltegger (Geneva).

Holotype. Specimen PIMUZ 28563 (Pl. 4, Fig. 1a–e).

Type locality. Nammal, Salt Range, Pakistan.

Type horizon. Sample Nam802, top of CS, *Euflemingites cirratus* beds.

Diagnosis. Compressed *Arctoceras* without true tubercles but with weak ribs thickening at umbilical margin; and with subtabulate venter.

Occurrence. Relatively abundant in sample Nam802.

Description. Moderately evolute, compressed shell. Flanks nearly flat with a slight depression near the umbilical margin, only slightly converging. Venter subtabulate with rounded shoulders. Umbilicus deep with vertical wall and marked but rounded shoulders. Ornamentation consists of slightly biconcave ribs that are most prominent near the umbilical margin, where they almost develop tubercles. Suture line ceratitic, third lateral saddle low and broad, auxiliary series short.

Measurements. See Appendix.

Discussion. This species is very similar to the slightly younger *Arctoceras meridionale* Guex 1978 from the lower part of the UCL of the Nammal section, which differs by its less platycone flanks, its more evolute coiling and its stronger, but very similar, ornamentation. That species is actually very close to *Brayardites* Brühwiler et al. (2010b) and may represent a transition form between the genera *Arctoceras* and *Brayardites*.

Typical *Arctoceras* from the paleoarctic realm differ from *A. schalteggeri* by their rounded venter and their more distinct tuberculation (e.g., Kummel 1961). *A. tuberculatum* (Smith 1932) from the Western USA and *A. subhydaspis* (Kiparisova 1961) are similar but differ by their more distinct tuberculation. *A. strigatus* Brayard and Bucher 2008 is very similar, but differs by its strigation, absence of umbilical tuberculation and a suture line with longer and slenderer saddles.

Family Galfettitidae Brühwiler and Bucher (2011b)

Genus *Vercherites* Brühwiler, Ware, Bucher, Krystyn & Goudemand (2010b)

Type species. *Koninckites vercherei* Waagen, 1895.

***Vercherites wyleri* sp. nov.**

Plate 3, figs. 1–4

Derivation of name. Named for Daniel Wyler (Zürich).

Holotype. Specimen PIMUZ 28558 (Pl. 3, fig. 1a–d).

Type locality. Nammal, Salt Range, Pakistan.

Type horizon. Sample Nam802, top of CS, *Euflemingites cirratus* beds.

Diagnosis. *Vercherites* with tabulate venter on the inner whorls, which becomes rounded on the outer whorls; flanks with weak plications; suture line with a relatively short auxiliary series.

Occurrence. Rather abundant in sample Nam802.

Description. Moderately evolute, compressed shell. Flanks, convex and convergent. Venter, narrow and tabulate with slightly rounded shoulders on the inner whorls, becoming broader and rounded on the outer whorls. Umbilicus with vertical wall and marked but rounded shoulders. Surface, smooth except for slightly biconcave growth lines and weak plications that are most prominent at the mid-flanks. Suture line, simple and ceratitic with rather weakly indented lobes and a short auxiliary series.

Measurements. See Appendix.

Discussion. The older *Vercherites vercheri* (Waagen 1895) from the CM and *V. pulchrum* (Waagen 1895) from the CS are similar but differ by their narrower and more tabulate venters (Brühwiler et al. 2011b). *Paranorites ambiensis* (Waagen 1895) differs by its distinct suture line with a narrow and phylloid first lateral saddle. *V. wyleri* sp. nov. differs from *Arctoceras schalteggeri* sp. nov. described above by its different type of ornamentation and its gently curved flanks. *Lepiskites* Dagys & Ermakova 1990 differs by its ribbed inner whorls and its suture line with a long auxiliary series.

Family Melagathiceratidae Tozer 1971

Genus *Juvenites* Smith 1927

Type species. *Juvenites kraffti* Smith 1927.

***Juvenites* sp. indet.**

Plate 4, fig. 3a–e

Occurrence. A single, very small specimen from sample Nam802.

Description. Moderately involute, subglobose shell. Venter, broadly rounded. Umbilicus, deep with vertical wall and well-rounded shoulders. Ornamentation consists of strong constrictions. Suture line, ceratitic with only two lateral saddles and weakly indented lobes.

Measurements. See Appendix.

Discussion. Our single specimen is possibly conspecific with the slightly younger *Juvenites* sp. indet. from the *Brayardites compressus* beds at Nammal (Brühwiler et al. 2011b), but its small size hinders a specific assignment.

Family incertae sedis

Genus *Kraffticeras* Brühwiler et al. (2011a)

Type species. *Meekoceras pseudoplanulatum* Krafft & Diener 1909.

***Kraffticeras pseudoplanulatum* (Krafft & Diener 1909)**

Plate 4, fig. 5a–e

1909 *Meekoceras pseudoplanulatum* Kraft & Diener, p. 30, pl. 6, fig. 3a–c

acc. *Kraffticeras pseudoplanulatum* (Krafft & Diener 1909) - Brühwiler et al. (2011a).

Occurrence. Two small specimens from sample Nam802.

Description. Moderately involute, compressed shell. Flanks, nearly flat, only slightly convex and convergent. Venter, bicarinate. Umbilicus, deep with vertical wall and subangular shoulders. Surface, ornamented with weak plications that are most prominent near the umbilical margin. Suture line with long saddles and deep, apparently not indented lobes.

Measurements. See Appendix.

Discussion. This species has recently been described from the upper part of the *Flemingites* beds at Losar, Spiti (Brühwiler et al. 2011a). Thus, it is an important taxon for the correlation of the ammonoid succession from the Salt Range with that of Spiti.

Superfamily Sageceratаceae Hyatt 1884

Family Hedenstroemiidae Waagen 1895

Genus *Hedenstroemia* Waagen 1895

Type species. *Ceratites hedenstroemi* Keyserling 1845.

***?Hedenstroemia* sp. indet.**

Plate 4, fig. 4a–c

Occurrence. A single fragmentary specimen from sample Nam802.

Description. Very involute, compressed shell. Flanks, convergent. Venter, narrow, probably slightly bicarinate, but poorly preserved. Umbilicus, small and deep with vertical wall and subangular shoulders. Surface, smooth except for fine, distinctly biconcave growth lines. Suture line not preserved.

Discussion. Our single specimen is identical to the inner whorls of *Hedenstroemia evoluta* Spath 1934 from the *Clypeoceras superbum* beds of the Salt Range (Brühwiler et al. 2011b). However, since the suture line is not preserved in this specimen, the assignment to *Hedenstroemia* is only provisional.

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Appendix

Measurements of the classic geometrical parameters of the ammonoid shell. Diameter (D), whorl height (H), whorl width (W) and umbilical diameter (U).

Species	Specimen	*D* (mm)	*H* (mm)	*W* (mm)	*U* (mm)
Kashmirites weisserti sp. nov.	PIMUZ 28552	47.4	16.1	–	20.7
	PIMUZ 28553	32.8	12.6	–	11.7
	PIMUZ 28554	34.3	12.8	11.1	13.5
	PIMUZ 28555	28.5	9.2	7.8	12.9
	PIMUZ 28556	10.6	3.2	4.5	5.2
	PIMUZ 28557	44.7	14	13	20.3
	PIMUZ 28569	39	14.7	–	15
	PIMUZ 28571	36.8	14.5	10.4	13.5
	PIMUZ 28574	27.2	9.4	–	10.6
Vercherites wyleri sp. nov.	PIMUZ 28558	100.4	42	–	29.7
	PIMUZ 28559	51.4	23.8	13.7	12.3
	PIMUZ 28560	34.2	14.5	8.9	10.9
	PIMUZ 28561	34.2	15	8.6	9.4
Arctoceras schalteggeri sp. nov.	PIMUZ 28562	69	30.3	–	17.9
	PIMUZ 28563	47.7	21.6	12.5	11
Juvenites sp. indet.	PIMUZ 28564	7.4	3	4.9	2.6
Euflemingites cirratus (White 1880)	PIMUZ 28567	54.5	24.4	16	16
	PIMUZ 28569	103	40.3	26	33
Kraffticeras pseudoplanulatum (Krafft & Diener 1909)	PIMUZ 28572	15.1	7.3	4.2	3.7

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